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A Review

Influence of Dietary Fiber Levels on Feed Utilization and Growth Performance in Poultry

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Abstract

The maintenance of poultry health is complex and relies on a delicate balance diet. Dietary fiber (DF) is a dietary component has a major influence in this regard. Utilization of fiber in the poultry diet as a supplements play an important role in poultry health as well as poultry production. Nowadays with increasing human population around the world the Utilization of natural source is a marketable point of enhancing more poultry production. DF is a heterogeneous class of components that is not hydrolyzed by the digestive enzymes of non ruminant animals, and consequently are the main substrates for bacterial fermentation in the distal part of the gut. This review presents evidence that some components of dietary fiber may improve poultry health and performance.

Keywords: Plant fiber, poultry diets, poultry productive performance, gastrointestinal tract.

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Introduction

Natural plants fibre source could be used as a possible nutritional and economical alternative source to supplement scavenging intake of free-range chickens, however there are only a few reports in the literature which evaluate utilization of natural plants fibre source for improving poultry health and production. Main objective of this review paper is mention to some advantage and disadvantage of utilization of fibre in poultry diet.

Definition of Fiber

McDonald *et al.*, (2002) define fibre as a term that refers to cell walls of plant tissue that mostly consist of lignin, cellulose as well as hemicelluloses. Further, it as the composition of plant cell that is resistant against enzymes in the small intestine. Moreover, from the chemical viewpoint, fibre is illustrated as non-starch polysaccharides. According to McNab and Boorman (2002), non-starch polysaccharides could be divided into two types of soluble and insoluble NSP. Based on a research conducted by Branton *et al.*, (1997), a non-contagious disease takes place in poultry every time that diet enriches of insoluble NSP results in more risk of necrotic enteritis. This is because of an increasing microbial fermentation in the intestine. The two terms of "crude fibre" and "roughage" are mostly applied synonymously in animal nutrition. Crude fibre refers to the structural carbohydrates made of cellulose, hemicelluloses and lignin in the plant cell wall while the composition of crude fibre in each single plant is different from other kinds of plants.

Fiber Requirements

The latest researches precisely recognize the percentage of crude fiber for poultry; crude fiber could be in a range from 3 to 4% for a greater period while it could be applied by 5% for layers. Generally, poultry-feed manufacturers and poultry producers believe that fiber content must be kept below 7% in poultry feed. Fiber is viewed negative as it declines production as well as chicken growth. That is, it looks to decrease the effectiveness of feed utilization. According to a recent survey, nevertheless, the chickens' welfare may be improved due to the fiber in the feed from two facets mentioned below. First, chickens that were fed with lower quantities of fiber suffered from cannibalism more than those that were fed with diets of higher fiber. Perhaps, this is because of the longer period of time they needed to digest such high-fiber feed or for the reason that they were given more feed. Still, the exact relationship is under study.

Secondly, fiber ingredients in laying hens' diet could decrease the ammonia emission in their manure, as indicated by another research. In order to provide energy for good-bacteria, fiber in the chickens' digestive tract replaces some of the nitrogen (nitrogen changes into uric acid and then leads to ammonia emission). Additionally, the raise of bacterial metabolism changes ammonia into ammonium and for chickens' health ammonium is less volatile. Briefly, in order to improve the chickens' welfare, a higher fiber diet must be applied.

Dietary fiber is indispensable for regulating digestion in broilers and laying hens. The fermentation in the small intestine is aided by high-starch diets while pathogens could multiply very fast and harm the digestive processes of poultry.

Utilization of Fiber in the Monogastric Animals

Ostriches, like pigs and poultry, are monogastric animals. Angel (1996) describes ostriches as herbivores (plant-eaters). Moreover, their digestive systems have adjusted to deal with large quantities of low-quality, fiber-rich plant material (roughage). Monogastric animals' lower digestive tract mainly digests and absorbs fiber-rich material. As shown in Table 1, the capacity of the digestive tracts of chickens, pigs and ostriches, as three common farm animal species, are graphically compared.

It goes without saying that an ostrich's lower digestive tract is much larger than that of poultry or a pig in connection with the total digestive tract. This very larger lower digestive tract is directly related to an animal's ability to digest fibrous materials. The lower digestive tract (colon or large intestine plus caecum) of poultry, pigs (Getty, 1975) and ostriches (Bezuidenhout & Van Aswegen,

1990) comprises around 11%, 21% and 61% of the whole digestive tract of the various species.

Table 1: The relative length of the small intestine, large intestine (colon) and caecum of the chicken, pig and ostrich (adapted from Getty, 1975 and Bezuidenhout & Van Aswegen, 1990).

	category	Small Intestine (%)	Large Intestine (%)	ceca
Ostrich	granivor/herbivore	39	48	13
Chicken	Granivore	89	2	9
Pig	omnivore	79	19	2

The pioneering study conducted by Swart (1988) also evidently showed the ability of the ostrich to use lower quality raw material. He pointed out that the ostrich can digest both cellulose and hemicelluloses. Besides, it was discovered that an ostrich could most likely obtain 12 to 76% of its energy in the form of volatile fatty acids (the end product of the digestion of fiber-rich feed in the large intestine). However, regarding pigs, Eggum *et al.,* (1982) assert that they also can digest fiber fractions (hemicelluloses) to a certain level and energy supply in the form of volatile fatty acids from the lower digestive tract may help 10 to 30% of their total energy requirements. Yet, with regard to chicken's lower digestive tract, it does not provide the animal with any energy.

Anatomy Ostrich and Fiber Digestion

The microflora of the cecum and large intestine is like that of the rumen while an ostrich is 3–6 weeks old. That is why Janssens *et al.,* (1996) believe that ostrich might be able to digest fiber from a young age. Nevertheless, Schiavone *et al.,* (1999) mentioned that ad libitum feeding of Lucerne from the age of seven days led to reduced growth rates and lower body weight at the age of 28 days compared with birds fed pelleted diets. This continued up to the age of three months.

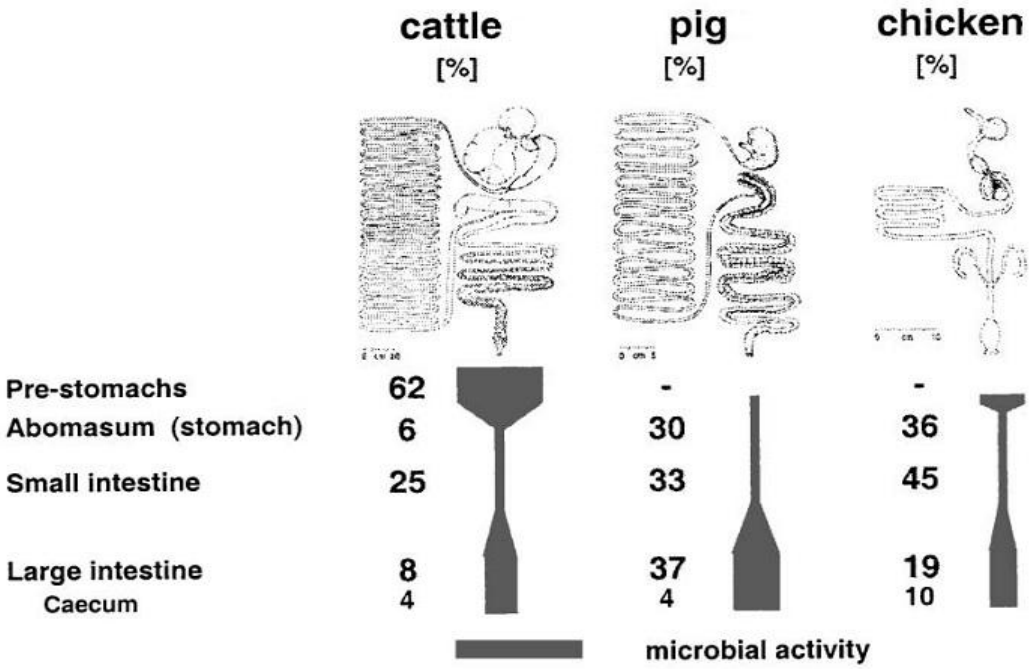

Fig. 1: Comparison of digestive tract of cattle, pigs and poultry.

The process in the digestive tracts of farm animals is of great importance in the understanding of the influence of nutrition on metabolism. In comparison to ruminant, non-ruminant animals have a 'simple' stomach, in which only slight microbial modification of available nutrients take place before absorption occurs. Micro-organism Are in contact with undigested materials or endogenous substrates to a considerable degree mainly in the lower parts of the digestive tract, from the terminal ileum to the rectum and the products of this microbial fermentation may partly be absorbed by the host animal.

Anaerobic conditions provide most of digestive processes in non-ruminants. Quantity and composition of the diet play an important role in feed digestion. The size of the digestive tract and passage rates as well as are more imperative characteristics. In Fig. 1, the digestive tract of the poultry is presented in comparison with pig and cattle.

The chicken, in comparison, has a crop before a gizzard (a muscular stomach) blew the true stomach (proventriculus), in which glands release endogenous secretions. If feed remains for a longer period in this organ microbial activity in the crop becomes critical. Small size and high passage rate in the small intestine of poultry lead to low microbial activity. The rate of passage in the large intestine comparison to pig is also faster, therefore, limiting microbial degradation.

The pig as a non-ruminant animal has an only small population of micro-organisms in the stomach relative to the lower parts of digestive tract. Furthermore, it should be noted that ingested feed remains only for a short period of time in the stomach. Therefore, microbial activity is rather limited, (Wenk, 2007).

Cecum fomenters (rabbit) have an enlarge cecum which retains solutes and small particles for fermentation. The larger herbivores such as horse, ass, zebra and elephant are the colon fermenting type, in which the contents of colon and cecum mix freely and act as one large fermentation site. These differences are illustrated in table 2. Foregut fermentation with the development of a pre-gastric microbial fermentation, multi-chambered stomachs have evolved.

Table 2: Comparison of percentage of the gastrointestinal tract among the rabbit (cecum fermentation), horse (cecum and colon fermentation) and sheep (foregut fermentation).

	Category	Cecum (%)	Colon (%)
Horses	herbivore	16	45
Rabbit	herbivore	30	6
Sheep	ruminant	2.3	10.4

Effect of Dietary Fiber in the Small Intestines and Apparent Digestion in the Turkey Hens

Turkey hens at three ages were fed with three crude fiber dietary concentrations in order to find out the possibility of using high fiber diets in their rations. Besides, performance, fiber digestibility and small intestinal morphology were established, too.

While diets contained 80 to 90 g crude fiber/kg growth, rate and feed efficiency declined but growth did not change when 60 g crude fiber/kg was fed between 1 and 4 weeks or between 6 and 8 weeks and was increased between the age of 11 and 14 weeks.

At fiber intakes of 80 to 90 g/kg between 1 and 4 weeks, digestibility's of crude protein, fat and gross energy (GE) decreased but not at later ages. Age enhanced crude fiber digestibility and dietary fiber content reduced it.

High dietary crude fiber intake enhanced total small intestinal length and surface area between 11 and 14 weeks. As a result of feeding the various crude fiber concentrations, small yet inconsistent variations in the length, diameter and number of villi, villus size as well as area were detected in the duodenum, jejunum and ileum at the different ages.

Turkeys can use crude fiber slightly and concentrations of 60 g fiber/kg in the diet did not cause reduced performance after the age of 6 weeks. (Sklan *et al.*, 2003).

Effect of different sources of dietary fibre on growth performance, intestinal morphology and social carbohydrates of domestic geese

The research intended to investigate the effects of dietary fibre sources on growth as well as on the development of the gastro-intestinal tract among growing geese.

Six-week-old female White Roman geese were randomly divided into six groups with six dietary treatments. Diets were isoenergetic and isonitrogenous and consisted of alfalfa meal, barley bran, rice hulls, cellulose, pectin or lignin as the main dietary source of fibre.

Food intake in the barley bran group, compared with the other groups, was considerably higher. Besides, not only daily weight gain but also food conversions of the pectin and alfalfa meal groups were by far lower than those of the other groups.

In terms of the relative weight and the length of the small intestine in the 9-week-old geese, no extensive change was observed among treatment groups. The relative weight in the pectin group, nonetheless, was notably the lightest and the caecal length was considerably the shortest ($P< 0.05$).

Moreover, in the pectin group, the activities of amylase and cellulose hydrolases of the cecal contents were the highest.

Effect of Mash Dietary Fiber on Performance and Cannibalism in Laying Hens

In order to detect the effect of dietary fiber given in mash form on laying hens' performance and cannibalism mortality, an experiment was carried out. For a period of 12 weeks, three various diets including a wheat-based diet, a guar gum diet (a wheat-based diet + 20 g/kg guar gum) and a Lucerne meal diet (a wheat-based diet + 40 g/kg Lucerne meal) in mash form were given to the birds. The outcomes indicated that birds fed guar gum diet, compared with those fed other diets, had the lowest intake ($p<0.01$), egg weight ($p<0.05$), body weight ($p<0.05$) as well as the lowest egg production ($p<0.01$). The effect of diets on a feed to egg ratio and cannibalism mortality was not significant ($p>0.05$). However the birds fed the guar gum diet had numerically the highest mortality (11.3%) and the Lucerne diet had the lowest (6.9%). The lack of deep variations was most likely because of the diets that were given in mash form. In brief, diets consisting of high soluble NSP decreased the performance and raised the mortality because of cannibalism among laying hens. Perhaps, the application of mash form might potentially decline the negative effect of soluble NSP on cannibalism.

The Influence of Fiber Content and Physical Texture of the Diet on the Performance of Broilers in the Tropics

The effect of dietary fiber and physical form on food consumption was not significant. Pollution increased growth and food utilization. In contrast, they dropped via increasing fiber content. Further, the fiber and physical form interaction was significant.

High fiber contents, at similar food intakes, enhanced relative length and weight of the intestine and ceca. In broilers fed on four of the five mash diets gizzards were much heavier. (Abdelsamie *et al* .,1983).

Nutritive Values of Some Tropical (West African) Legumes for Poultry

In order to examine the impact of increasing the dietary amounts of jack beans, kidney beans, lima beans, yam beans, pigeon peas and Bambara groundnuts on the performance of broiler chickens a study was done. The inclusion of legumes, even at the 12.5% level, led to major cuts in weight gains and feed intakes. The amount of feed consumed (kg) per kg weight gain for broilers offered diets including 12.5% lima beans, pigeon pea and 12.5 or 25%. Bambara bean or yam bean did not vary mainly from the control group. In addition, inclusion of jack bean and kidney bean at both levels and lima bean or pigeon pea at the 25% level negatively influenced the efficiency of feed conversion. By means of higher levels of dietary treatments, the weights of liver and brain were significantly changed ($P<0.05$). Serum total protein and albumin levels commonly declined with 25% legume concentration in the diets. However, urea and creatinine levels raised Transaminase and phosphatase enzyme activities were normally promoted on a higher level of legume feeding. Therefore, just a pigeon pea and Bambara nut could be suggested for inclusion in poultry rations.

Nevertheless, if it is proposed to be fed over a longer period of time, the vigil is required.

Effects of Different Sources of Dietary Fiber on Growth Performance and Apparent Digestibility in Geese

In the first research, sixty two-week-old female White Roman geese were used. In addition, eighteen mature female geese were colostomized, placed in metabolism cages and were used for a digestion study in the second experiment. The experimental diets for the six various treatments were enhanced with alfalfa meal, barley bran, rice hulls, or purified cellulose, lignin, or pectin, respectively as the main source of fiber. They were formulated into isoenergetic and isonitrogenous diets with 90 g kg−1 of crude fiber.

In terms of gaining body weight, geese fed the pectin supplemented diet indicated considerably less gain than the other treatment groups ($P < 0.05$) because of lower feed intake. Those in the lignin group consumed notably more feed than the other geese ($P < 0.05$), and revealed the lowest feed conversion. Nonetheless, sources of dietary fiber could not extensively influence the feed conversion. The sources of dietary fiber failed to influence the relative ratio of different volatile fatty acids (VFA). On the other hand, they considerably affected total VFA concentration of the caecal contents ($P < 0.05$) that was the highest in the pectin group (97.07 mmol 1−1). In addition, in the diet with a lignin or a pectin supplement, digestibility of crude protein and gross energy were drastically lower ($P < 0.05$), (Hsu *et al* .,1996).

Effect of Dietary Fibre on Growth Performance and Serum Parameters for Landes Goose

One hundred and ninety Landes geese, each weighing about 2.4 kg, were selected in order to study the impacts of diets containing various crude fiber levels (4%, 8%, and 12%) with equal energy and protein on bird growth performance, dressed performance and partial blood biochemical indexes. Ten geese died for checking dressed performance prior to the experiment, and the rest of them (180) were divided into three treatment groups by sex and fed for four weeks, three repeats per treatment and twenty birds per repeat. In the test diet, rice hull meal was used as the major fiber sources. The results indicate that: (1) Diet including crude fiber of 8% results in the highest growth performance and varies considerably ($p<0.05$). (2) Additional increase of dietary fiber leads to significant impact on serum indexes including total cholesterol (TC), triglyceride (TG), low density lipoprotein (LDL), very low density lipoprotein (VLDL), high density lipoprotein (HDL), alkaline phosphatase (AKP), amylase (AL), glutamate-pyruvate transaminase (GPT) and glutamic-oxalacetic transaminase (GOT) ($p <0.05$) plus on dressed performance ($p< 0.05$) yet no significant impacts on urea acid (UA), urea (UR), glucose (GLU), as well as total protein (TP) ($p>0.05$). (3) A drawn poultry of lower adipose tissue is the result of high fiber level. Perhaps, VLDL is a limiting element for lipid synthesis in the Landes goose (Shixia & Na, 2006).

Effect of Different Fibre Level Diets on Normal Microbiological Floras in Goose Intestines

In order to study the impact of various proportions of Leymus chinensis on normal microbiological floras in four parts (duodenum, jejunum, ileum and caecum) of intestines of adult egg-laying goose, the quantitative method of diluted inoculability was applied. The outcome demonstrated that Bifidobacterium in the intestines with a logarithmic value of 8.12±0.8 were the dominant bacteria. The next ones were Clostridium and Lactobacillus with the logarithmic value of 7.98±0.4 and 7.33±0.4. The number of bacteria in caecum, compared with that in the other intestinal segments, was significantly higher ($P<0.01$). Additionally, the number of bacteria of the high fiber group, compared with that of the low fiber group, was larger ($P<0.01$) and that of gander was higher than goose ($P<0.05$). The number of Bifidobacterium, Clostridium and Lactobacillus, compared with that of the other bacteria, was considerably larger and they were the principal bacteria floras among egg-laying goose (Zhang *et al.,* 2007).

Development of the Gastrointestinal Tract and Digestibility of Dietary Fiber and Amino Acids

among Young Chickens, Ducks and Geese Fed Diets with High amounts of Barley

The study consisted of fifty chickens, forty ducks and thirty geese fed a diet including 40% barley. The birds in this study were kept in metabolic cages from 1 to 42 days of age. During the last week of the birds' lives, a balance trial was performed and the apparent digestibility of nutrients was measured. At the age of 21 and 42 days, 12 animals per species died. The absolute length of intestines was based on the animals' live weight (LW). With regard to metabolic LW (kg0.67), the overall length was considerably higher in chickens and geese than that in ducks at the age of 21, yet exactly the same in the three species at the age of 42 days. Unlike in chickens and in geese, in ducks the absolute and relative weights of intestines were smaller at the age of 21 and 42 days. Chickens could digest dietary fiber much better than ducks and geese ($P<0.01$). Ideal digestibility of total amino acids reached to 76% in chickens, 69% in ducks ($P>0.05$) and only 56% in geese ($P<0.01$) with comparatively low digestibility of methionine (70, 44 and 52%) and lysine (72, 57 and 41%) respectively. For all three species, the whole tract–fecal digestibility of total amino acids was calculated on the level of 86% and the results revealed a significant hind gut synthesis of amino acids, (Jamroz *et al.*, 2001).

Leucaena Leucocephala in Poultry Nutrition

This has been the subject of many studies during the last decade. The latest data verify the earlier findings about the favorable proximate composition of Leucaena leaf meal (LLM) even though the carotenoid content of this legume is currently appearing as its major asset for the pigmentation of egg yolks and broiler carcasses.

Toxicological evaluation is still a chief characteristic of research on Leucaena. After the latest innovative improvements in analytical chemistry, nowadays there is more reliable information related to the concentration of mimosine in the LLM and seeds and to the degradation of this amino acid to 3-hydroxy-4 (1H) -pyridone. In addition, in this article, data on the concentrations of tannins, trypsin inhibitors, galactomannan gums, saponins and flavonols are reviewed. Detoxification of Leucaena for poultry remains a big problem because there are restrictions to conventional approaches like plant breeding as well as the application of heat treatments. Perhaps, via the application of dietary additives like ferric sulphate and polyethylene glycol, significant amelioration of the adverse effects of LLM can be achieved. These developments, nonetheless, depend on suitable adjustments for lower apparent Metabolizable energy (AME) value of LLM. Therefore, in spite of the latest advances, the low AME of LLM would be a difficult subject for the future (Ologhobo, 1992).

Assessment of Leucaena Leucocephala Leaves as Feed Supplement in Laying Hens

In poultry feed production in the tropics, the protein source is a limiting factor. Thus, the appropriateness of leaves of Leucaena leucocephala, a protein rich multi-purpose leguminous plant, as feed supplement in laying hens was examined at 50, 100 and 200 g/kg (5, 10 and 20%) supplementation levels. Leucaena supplementation drastically reduced weekly average daily egg lay ($P < 0.01$) and increasingly declined cumulative weekly average daily egg lay to 88.2, 68.7 and 53.4% for 5, 10 and 20% supplementation levels, respectively. Besides, a converse relationship was observed between level of L. leucocephala supplementation and weekly average daily egg lay ($r = -0.99$) that extremely correlated with the crude fiber content of the diets ($r = 0.94$). The various levels of Leucaena supplementation could not have a considerable effect on the eggs' size and specific gravity ($P >0.05$). Based on the outcomes, it could be recommended that L. leucocephala leaves may only be appropriate as feed supplement among egg laying hens at low levels of supplementation, (Atawodi *et al.*, 2008).

Conclusions

Diet among other environmental and genetic factors, is currently recognized to have an important role in health and disease. One of the present challenges in nutritional science is to improve utilization of natural fiber sources especially during the highly sensitive neonatal and weaning stages of

life. In this context, moderate levels of DF in diet for poultry seem to be beneficial for bird health. Currently, there is still much to learn about the consequences of these Interactions in terms of animal and human health.

References

Abdelsamie RE, Ranaweera KNP & Nano WE (1983). The influence of fibre content and physical texture of the diet on the performance of broilers in the tropics. Br. Poult. Sci., 24(3): 383-390.

Angel CR (1996). A review of ratite nutrition. Anim. feed sci. tech., 60(3): 241-246.

Atawodi SE, Mari D, Atawodi JC & Yahaya Y (2008). Assessment of Leucaena leucocephala leaves as feed supplement in laying hens. Afr. J. Biotech., 7(3): 317-321.

Bezuidenhout AJ & Aswegen GV (1990). A light microscopic and immunocytochemical study of the gastrointestinal tract of the ostrich (Struthio camelus L.). Onderstepoort J. Vet. Res., 57(1): 37-48.

Brand TS, Nell CJ & Van Schalkwyk SJ (2000). The effect of dietary energy and protein level on the production of growing ostriches. South Afr. J. Anim. Sci., 30(4): 15-16.

Branton SL, Lott BD, Deaton JW, Maslin WR, Austin FW, Pote LM & Day EJ (1997). The effect of added complex carbohydrates or added dietary fiber on necrotic enteritis lesions in broiler chickens. Poult. Sci., 76(1): 24-28.

Dehority BA (2002). Gastrointestinal Tracts of Herbivores, Particularly the Ruminant: Anatomy, Physiology and Microbial Digestion of Plants. J. Appl. Anim. Res., 21: 145-160.

Eggum BO, Andersen JO & Rotenberg S (1982). The effect of dietary fiber level and microbial activity in the digestive tract on fat metabolism in rats and pigs. Acta. Agr. Scand., 32(2): 145-150.

Glatz PC, Ru YJ, Hastings MY, Black D & Rayner B (2003). On farm assessment of high fibre dietary sources for grower and finisher ostriches. Int. J. Poult. Sci., 2: 293-299.

Getty R (1975). Sisson and Grossman's Anatomy of Domestic Animals. 5th ed. Philadelphia: Saunders; pp. 960-1023.

Hsu JC, Lu TW, Chiou PW & Yu B (1996). Effects of different sources of dietary fibre on growth performance and apparent digestibility in geese. Anim. feed sci. technol., 60(1): 93-102.

Jamroz D, Jakobsen K, Orda J, Skorupinska J & Wiliczkiewicz A (2001). Development of the gastrointestinal tract and digestibility of dietary fiber and amino acids in young chickens, ducks and geese fed diets with high amounts of barley. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiol., 130(4): 643-652.

Janssens GPJ, Seynaeve M, de Wilde RO and deRycke H (1996). Nutritional aspects of the ostrich (Struthio camelus). Vlaams Diergeneeskundig Tijdschrift., 66: 153-160.

Mehner A, Hartfiel W (1983). Handbuch der Geflügelphysiologie. Karger.

McDonald JC & Whitesides GM (2002). Poly (dimethylsiloxane) as a material for fabricating microfluidic devices. Accounts chem. Res., 35(7): 491-499.

McNab JM and Boormann KN eds. (2002). Poultry feedstuffs [electronic resource]: supply, composition, and nutritive value. No. 26. CABI.

Ologhobo AD (1992). Nutritive values of some tropical (West African) legumes for poultry. J. Appl. Anim. Res., 2(2): 93-104.

Schiavone A, Pirei S and Romboli I (1999). Lucerne hay (Medicago sativa) supplementation in ostrich chick (Struthio camelus) feeding: preliminary results. Annali Della Facolta di Medicina Veterinaria di Pisa., 52: 275-281.

Sklan D, Smirnov A & Plavnik I (2003). The effect of dietary fibre on the small intestines and apparent digestion in the turkey. Br. Poult. Sci., 44(5): 735-740.

Swart D & Rahn H (1988). Microclimate of ostrich nests: measurements of egg temperature and nest humidity using egg hygrometers. J. Comp. Physiol. B., 157(6): 845-853.

Swart D (1988). Studies on the hatching, growth and energy metabolism of ostrich chicks: Struthio Camelus var. Domesticus (Doctoral dissertation, Stellenbosch: University of Stellenbosch).

Shixia LXHRZ & Na WCZ (2006). Effect of Dietary Fibre on Growth Performance and Serum Parameters for Landes Goose [J]. Journal of the Chinese Cereals and Oils Assoc., 3: 041.

Wenk C (2007). Secondary Effects of Dietary Fiber in the Nutrition of Monogastric Farm Animals. Sekundärwirkungen VON Futterinhaltsstoffen-VOM Nährstoff ZUM Wirkstoff, 10.

Yu B, Tsai CC, Hsu JC & Chiou PS (1998). Effect of different sources of dietary fibre on growth performance, intestinal morphology and caecal carbohydrases of domestic geese. Br. Poult. Sci., 39(4): 560-567.

ZHANG MA, WANG BW, LONG FY, WANG L, YANG ZG, ZHANG XH & LIU GL (2007). Effect of different fiber level diets on normal microbiological floras in goose intestines [J]. J. Fujian Agr. Forest. Univ., (Natural Science Edition), 2: 011.